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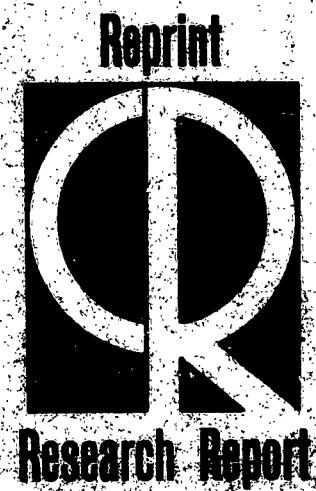


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## A Unipolar Structure Applying Lateral Diffusion

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A UNIPOLAR STRUCTURE APPLYING LATERAL DIFFUSION

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### **A Unipolar Structure Applying Lateral Diffusion\***

This communication describes a new method of fabricating a high transconductance, high-frequency unipolar structure by means of lateral diffusion. Design consideration for optimum performance of a unipolar device requires the channel between the source and drain to be narrow, short and uniformly doped.<sup>1,2</sup> (Fig. 1)

In addition, the gate region should be more heavily doped than the channel so that the depletion region will extend into the channel rather than into the gate.<sup>1,2</sup> The phenomena of lateral diffusion can be utilized to construct a silicon device corresponding to the description.

Narrow  $\text{SiO}_2$  masking strips are formed over the areas intended for channels (Fig. 1) in preparation for a boron diffusion. The boron then diffuses into the silicon, not only downward, but also laterally under the oxide stripe. It may be noted that the total

\* Received January 31, 1963.

<sup>1</sup> W. Shockley, "A unipolar field-effect transistor,"

Proc. IRE, vol. 40, pp. 1365-1376; November, 1952.

<sup>2</sup> G. C. Dacy and I. M. Ross, "The field effect transistor," Bell Syst. Tech. J., vol. 34, pp. 1149-1189; November, 1955.

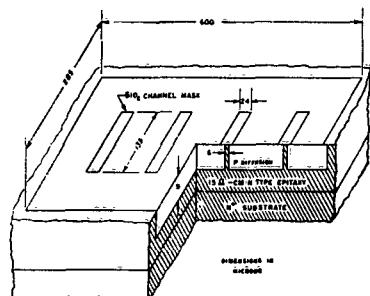


Fig. 1.

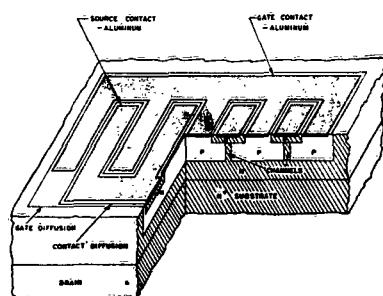


Fig. 2.

diffusion area is kept to a minimum to limit the gate capacitance.

Since the lateral diffusion determines the ultimate width of the channels, it is possible to accurately control this critical dimension. Since the extent of the lateral diffusion approximates the diffusion depth, it is possible to form channels of the desired width simply by controlling the diffusion depth. The resulting diffused area serves as the gate and the essential unipolar structure is then complete with just one diffusion. Since the gate extends completely around the channel, application of reverse bias drives the depletion region into the channel from all sides. The resulting configuration is similar to one for which a patent was applied,<sup>3</sup> but the method of fabrication is new. It should be noted that slight irregularities in the edges of the oxide masks lead only to irregularities in the channel cross sections. Since a channel formed by lateral diffusion may be described as many minute vertical channels operating in parallel, the effect of mask irregularities is just a slight modification of the over-all device characteristic.

The photomasking problem is no worse in this application than in conventional planar transistors, since the lateral diffusion forming the channel may be done using an oxide mask two to four times wider than the desired channel. In the device currently under investigation, the channel width is 6 microns. Since present difficulties with mask alignment and the etching process have prevented the cutting of contact openings into such a narrow stripe, a second diffusion is carried out to enlarge the source contact. This is accomplished by growing a

new oxide over the device and then etching 36 micron windows over the channels. A 3 micron deep,  $n^+$ , phosphorus diffusion results in the configuration shown in Fig. 2. The device is built into an  $n$  type, 15 ohm-cm, 15-micron deep epitaxially grown layer. The substrate is 0.01 ohm-cm silicon chosen to reduce the series resistance.

Using the Shockley analysis for unipolar devices,  $f_{max}$  for this device is approximately 1 kMc. An RC analysis of the device gives about the same frequency response if the capacitance of the diffused source contact is neglected. Improved photomasking techniques will eventually permit the elimination of the diffused source contact and this capacitance.

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<sup>3</sup> Patent Application submitted June 6, 1960, "Method of Making Improved Unipolar and Analogue Transistors" by C. E. Ryan, AFCRL.